

Review of FEWS NET biophysical monitoring requirements

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Abstract. The Famine Early Warning System Network (FEWS NET) provides monitoring and early warning support to decision makers responsible for responding to famine and food insecurity. FEWS NET transforms satellite remote sensing data into rainfall and vegetation information that can be used by these decision makers. The National Aeronautics and Space Administration has recently funded activities to enhance remote sensing inputs to FEWS NET. To elicit Earth observation requirements, a professional review questionnaire was disseminated to FEWS NET expert end-users; it focused upon operational requirements to determine additional useful remote sensing data and, subsequently, beneficial FEWS NET biophysical supplementary inputs. The review was completed by over 40 experts from around the world, enabling a robust set of professional perspectives to be gathered and analyzed rapidly. Reviewers were asked to evaluate the relative importance of environmental variables and spatio-temporal requirements for Earth science data products, in particular for rainfall and vegetation products. The results showed that spatio-temporal resolution requirements are complex and need to vary according to place, time, and hazard; that high resolution remote sensing products continue to be in demand, and that rainfall and vegetation products were valued as data that provide actionable food security information.

Keywords: applied remote sensing, requirements definition, Earth observations, early warning

Classification Codes: 07.60.-j, 07.87, 91.0, 91.62.Bf, 91.62.Ty, 91.62. Ry, 92.60. Uv, 93, 93.30, 93.30.Jg, 93.85.Pq

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1. Introduction

The Famine Early Warning Systems Network (FEWS NET) was created in 1985 by the Agency for International Development (USAID) to improve their emergency response capabilities in Africa, including disseminating information and increasing food security (Brown, 2008). The goal of “early warning” (USAID, 2007) is the timely and effective delivery of information that allows affected individuals to take action both to avoid and/or reduce their risk and to prepare for effective response (Buchanan-Smith and Davies, 1995). Key elements of a successful early warning system include accurate forecasts of the human consequences of an event when predicting its location, time, and severity; and warnings disseminated in time for populations at

risk to take appropriate action (Davies et al., 1991). FEWS NET provides early warning information to USAID through a suite of data products that support decision-making on how to anticipate and respond to episodes of food insecurity so that the human and financial toll of the disaster can be reduced.

Monitoring information, including Earth science remotely sensed data, and ground-based meteorological, crop, and rangeland conditions, strengthens the abilities of FEWS NET to manage the risk of food insecurity. FEWS NET's representatives work to build consensus about what the food security situation is in each country. When a crisis is building, a wide variety of actors must both understand and agree about the nature of the problem and, more importantly, the solution. These actors include local, regional and national government officials from the executive branch, health departments, meteorological departments and others, non-profit organizations who are active in the area, international aid organizations such as the World Food Program, and key analysts who work on food security. The complexity of actors and the overwhelming need for consensus means that remote sensing derived data take on new meaning, as the data are viewed as politically neutral, are easy to understand and are the earliest source of information on an emerging problem. Thus remote sensing information is critical to FEWS NET's ability to move from discussion of an impending threat to a decision that food aid is actually needed in a particular area (Brown, 2008). It is also a key input when a biophysical hazard such as a drought occurs, enabling decisions to be made about the number of people needing assistance, the geographic area affected, and the need for non-food assistance such as vaccinations, maternal and child health programs and water delivery.

Remote sensing information provides data on the presence and current weather, water and crops. FEWS NET is unique because it provides information about the impact of these biophysical conditions on the food security in the region, a strictly social, political and economic phenomenon. As an illustrative example, the late start of rains in specific parts of the Sahel in 2006, were a constant food security issue, lurking behind the good rainfall totals that then occurred in much of the Sahel after the late start. The primary food security drama in the Sahel at the beginning of the season was not only about the good rains, but whether and when we could tell they would go on for longer than normal, especially in those specific food security fragile parts of the Sahel where they started late. Through monitoring of remote sensing, FEWS NET can develop new tools and techniques which can lead to an improved regional understanding of the threat of a serious food crisis. Although agricultural production was ultimately above average, tracking the progression of the growing season in order to provide the earliest warning of trouble is a central part of FEWS NET's work.

Additional types of Earth science data would be useful to both increase the functionality of FEWS NET and address new institutional needs. Since the individuals who actually provide this type of data are generally not those who define the underlying requirements, such as data precision or the optimal resolution in the spatial and temporal domains, this questionnaire format study was initiated to determine the expert end-user's Earth science remote sensing requirements necessary to enhance FEWS NET functionality.

1.1. FEWS NET and biophysical remote sensing data

FEWS NET uses an integrated approach to continually evolve and improve its capacity for vulnerability assessment and early warning of food insecurity in support of humanitarian response programs. FEWS NET field and Washington offices gather and assess a wide variety of early warning, food access and availability, and vulnerability data and information in order to determine the food security status of a region. Through building of networks, FEWS NET representatives work to improve the human and institutional food security assessment and early warning capacity of country and regional partners/networks through hands-on training. Representatives and remote sensing specialists based in the field also work to develop, test, and

implement new applied tools and methods for early warning and food security and vulnerability assessment (FEWS, 2005).

Almost all FEWS NET field offices produce monthly food security situation reports for each country. Alert reports are also prepared when the USAID determines food security status in a country or area is a problem, based upon the FEWS NET watch, warning, and emergency criteria. FEWS NET interprets the food security significance of biophysical and climate data based on year-to-year variations to help understand food production, threats to pastoral resources, wild food availability, and ultimately the agricultural economy as a whole (Brown, 2008). This information is integrated with socio-economic monitoring data (Verdin et al., 2005). FEWS NET relies upon (when available) vegetation, temperature, and rainfall data derived from remote sensing, atmospheric models, and local measurements to identify abnormally wet and/or dry periods. Presently, FEWS NET early warning is characterized by a weekly weather hazards assessment process that includes members of the National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA), U.S. Geological Survey (USGS), U.S. Department of Agriculture (USDA), USAID, and a variety of technical specialists in Africa, Central America, and Afghanistan.

1.2. FEWS NET current and planned datasets

FEWS NET uses extensive data types to summarize current climatic situations, including gridded rainfall data and vegetation data derived from satellite imagery. Rainfall images drive a variety of models that allow investigation of the direct effect of rainfall amount on crop production. Vegetation index data derived from satellite imagery can provide insights into vegetative cover response to rainfall. Because vegetation and rainfall images measure different parameters, both types of satellite observations are needed for hazard identification.

This professional review was initiated to provide FEWS NET analysts with new data to improve their decision-making capabilities. Examples include more accurate and higher resolution vegetation and rainfall datasets, and new temperature, precipitable water, and humidity data. Accuracy estimates and projections of these datasets 1, 2, and 3 months into the future will help food security analysts provide additional information to decision makers regarding future food aid needs. These new datasets will be available to FEWS NET personnel and all interested persons by the end of 2009.

FEWS NET's agricultural monitoring is global in extent, thus the temporal requirements for any parameter is driven by the more sensitive points in a crop's development, since at any given time there will tend to be a crop of some regional importance entering a critical time period in some part of the world. Even considering a single crop in a single region, though early crop development is critical, mid-season development such as grain-fill in rain-fed maize may often make dramatic swings in yield based on mid-season precipitation. FEWS NET uses data from all its products as needed throughout the different points of the growing season for each region, which are diverse – Central America, Haiti, Afghanistan, and in three regions of Africa.

2. Design and administration of professional review

FEWS NET expert end-users and experts in Earth science information content answered a fact-finding professional review, in the form of an online questionnaire, to quantify FEWS NET satellite remote sensing requirements. The end-users included FEWS NET and USGS field personnel associated with country and regional offices. The Earth science information content providers included members of a network of experts in areas including hazards, meteorology, and agriculture.

Three broad sections of user requirements were addressed in the questionnaire. The general requirements section included identification and ranking of environmental variables and the spatio-temporal properties needed in those variables. The rainfall requirements section covered particular needs associated with both measured and predicted rainfall. The vegetation

requirements section focused on vegetation monitoring and proposed predictions of vegetation status. The rainfall estimate being evaluated was NOAA's Rainfall Estimate (RFE) (Love et al., 2004) and vegetation estimates being evaluated were normalized difference vegetation index (NDVI) (Tucker, 1979) from the Global Inventory Modeling and Mapping Studies Advanced Very High Resolution Radiometer (GIMMS AVHRR) NDVIg 8 km dataset (Tucker et al., 2005), 1 km data from SPOT Vegetation (Maisongrande et al., 2004), and 500 m data from the Moderate Resolution Imaging Spectroradiometer (MODIS) (Huele et al., 2002).

The questionnaire also addressed the usefulness of specific FEWS NET decision support elements. This portion of the questionnaire established a baseline for a future benchmarking effort to measure the effect of the proposed FEWS NET enhancements.

The review questionnaire was made available in June 2007, and responses were accepted through July 2007. Reviewers were invited to participate who were identified as playing a key role in the process of collecting biophysical data and converting it to information products supporting food security decision making. This group was selected so as to provide insight into the collective professional judgement of FEWS NET biophysical information providers. 63 reviewers were invited in total. Of the invitees, 35 were nearer the end of the value chain (either from FEWS NET field offices or other closely aligned entities in regions where food security is closely monitored), and 28 were part of the information support infrastructure in the United States. 43 participants provided complete responses. Of these respondents, 20 were field personnel: 5 working in Central America/Haiti and 15 working in Africa. The remaining 23 respondents were U.S. government and contractor personnel from the 5 associated FEWS NET agencies. Forty-four percent of the reviewers had between 6 and 10 years of FEWS NET-related experience and almost 35% had over 10 years of experience. The reviewers had a variety of educational backgrounds: 32% had an agriculture degree and 21% had a degree in remote sensing science. Most respondents had either on-the-job training or some formal training in meteorology, remote sensing, or geographic information systems.

The goal of the questionnaire was to elicit information for enhancing FEWS NET via a suite of satellite-based standardized products specific for climate monitoring. However, because the users were familiar with both the strengths and weaknesses of different kinds of remote sensing datasets and of the currently available dataset selection, respondents tended to express their requirements more in terms of what they knew was possible rather than in terms of what was actually required. Therefore, although the questions were designed to elicit the most candid responses possible, the responses to more specific questions often tended to be based upon knowledge of existing sensor options. In particular, this collective tendency of the reviewing professionals might bias the spatial resolution findings toward users with less stringent needs.

3. Questionnaire response results

Overall, rainfall data was regarded as an essential component of famine early warning. A clear majority of respondents felt that data on crop yield estimates, vegetation, soil moisture, and flooding are vital as well. However, less than half of the group saw temperature, land cover, and humidity data as vital for early warning analysis (figure 1). When asked to cite the drivers for the requirements of FEWS NET analyses, the professional reviewers expressed concerns associated with the great diversity of food security-related challenges and logistical constraints. They specifically referred to issues related to both slow-onset concerns, such as drought, as well as extreme events, such as cyclones and flooding. They also described varying climate regimes (i.e., too much rain, not enough rain, cyclones, etc.) requiring different environmental data to assess the impact of climate on food production and food security. Early warning or forecasts of such diseases as malaria and Rift Valley fever were also cited as drivers. The available digital infrastructure also placed limits on the size of the datasets analyzed and distributed.

Figure 1 summarizes the respondents' opinions regarding the value of various environmental variables.

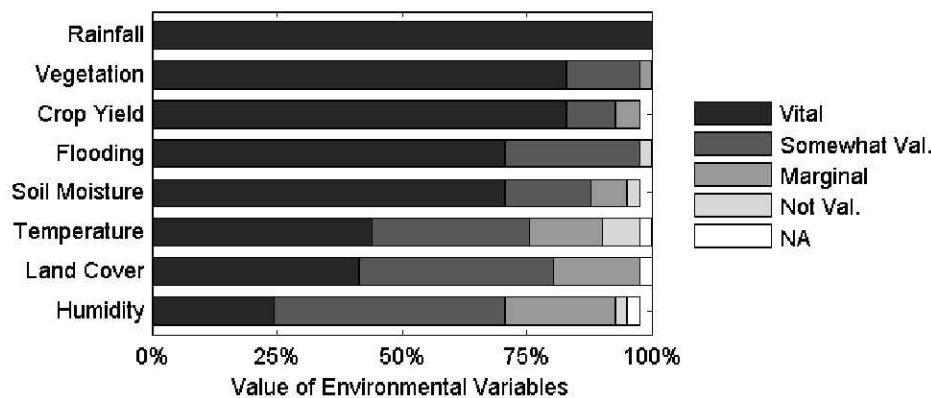


Figure 1. FEWS NET reviewers' ratings of the value of environmental variables.

3.1. Spatial requirements

Responses regarding spatial resolution are shown in figure 2a. If requirements analyses for output are properly defined, they should be traceable to input requirements for environmental variables. This review approached the problem of bounding spatial requirements by asking respondents to identify labels for the spatial scale of their principle analytical tasks. These labels from small to large included village, district, province, country & region. The review did not define these scale labels in terms of linear or area units; instead, the respondents were asked to provide a written response for the spatial resolution that they associated with scale labels chosen. For analysis scale, the dominant responses were "District" and "Country." Notably, among respondents who specified a quantitative spatial resolution, the most frequent resolution associated with "District" scale analysis was 250 m. These responses indicate that the spatial resolutions of current operational monitoring sensors are sufficient, since 250-m (MODIS) systems do provide this level of detail

While reviewers indicated spatial resolution of general observations were sufficient, when asked about specific parameters, they expressed concern about rainfall. Rainfall is critical to FEWS NET's representatives. Reviewers expressed a need for higher spatial and temporal resolution data related to rainfall because their work covers areas with diverse livelihoods and complex topography. Topography variations do not give a true image of actual ground conditions and makes generalizing information even at the district level difficult. The available rain gauge data is limited, especially in pastoral areas. Therefore, dissatisfaction with current 8-km resolution products was expressed by some; specifically, that this resolution was too coarse to capture important variations. High-resolution satellite rainfall imagery would improve the information quality, enable better analysis of food security hazards, and provide a higher confidence in the information and areas not covered by rain gauge data.

Additionally, Central America would benefit from higher spatial resolution products. The current 0.25 or 0.1 degree rainfall products are not suitable for detecting the rainfall variability which can be significant within the span of a single 10 km pixel.

Having data at multiple resolutions was expressed as important, because analyses are often conducted at highly variable resolutions; that is, from continental scale to sub-district scale. Consequently, as FEWS NET's ability to understand variations in livelihood zones improve, the necessity of finer spatial scale increases.

Questions regarding vegetation revealed that the desired resolutions were between 250 m and 1 km. In this case, rainfall spatial resolution needs were less stringent; resolutions between 2 km and 5 km were sufficient.

If connecting resolution with scale labels is a representative constraint, it is possible that some planned products will not meet all FEWS NET requirements. Spatial resolution needs to vary according to place, time, and hazard. Furthermore, as previously mentioned, perception of spatial resolution needed for analysis may be skewed by knowledge of the available sensor resolutions. In general, the findings presented in this paper represent the collective tendency of the reviewing professionals. Additionally, due to interpretation challenges, the spatial resolution finding may be biased toward users with more stringent needs.

Responses on spatial extent (figure 2b) were straightforward; over half indicated a need for regional or at least country coverage.

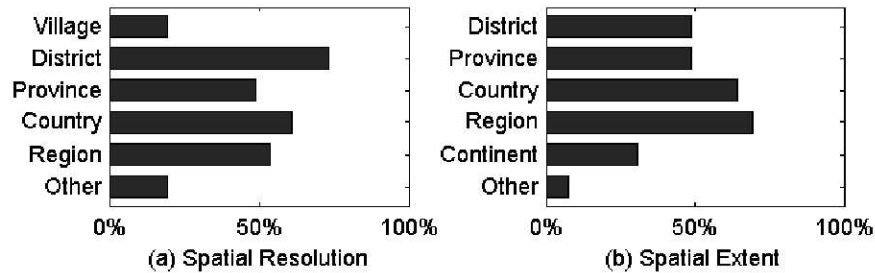


Figure 2. FEWS NET reviewers' identification of spatial qualities considered necessary for their analysis or decision-making. Note that reviewers were allowed to select multiple options as "necessary," so total response is greater than 100%.

3.2. Temporal requirements

Responses regarding temporal requirements overwhelmingly indicated that the traditional 10-day or dekadal time step (figure 3a) was most desired. Even though the dekad was clearly favoured, over half the respondents did say that monthly inputs were important and over 40% considered even daily data important.

For latency, data delivery within 1 day of acquisition was considered important both by environment monitoring experts and FEWS NET representatives (figure 3b).

The final temporal consideration was prediction time interval. Respondents stated that predictions looking both 1 week and 1 month into the future would be of particular interest (figure 3c).

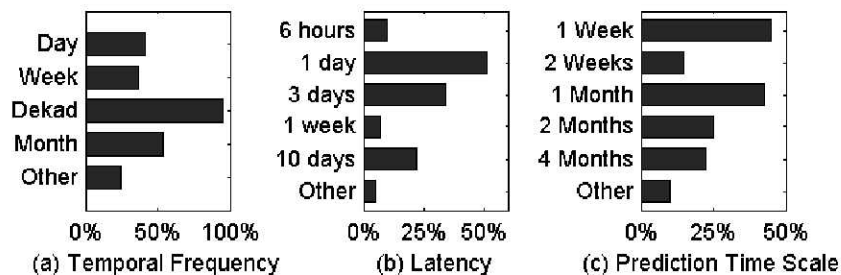


Figure 3. FEWS NET reviewers' identification of temporal qualities considered necessary for their analysis or decision making.

Each section of the questionnaire asked the reviewers for general comments about their requirements. Overall, responses indicated that the requirements depended upon the particular application. Data requirements for flood monitoring are obviously dependent on high temporal frequency/short latency data, such as rainfall, rainfall forecasts, stream flow, and runoff anomalies. Vegetation/Crop monitoring and modelling are not as time-sensitive and can use data with longer periods of both latency and frequency. Spatial requirements are also variable by

region. Again, an increasing need for much finer scale monitoring capabilities was expressed, whether for vegetation and rainfall monitoring over small areas or for cropped area delineations for small localized fields.

3.3. Results for rainfall value and accuracy

To evaluate specific environmental variables, the questionnaire asked the value of rainfall estimates at various prediction time scales up through 4-month forecasts. The reviewers' responses are summarized in figure 4a. Almost all respondents identified a rainfall monitoring product as "vital," and a majority thought a 1-month forecast to be essential. Beyond 1 month, the information became less relevant; however, a majority of respondents still saw 2- and 4-month forecasts as either valuable or somewhat valuable.

The questionnaire asked reviewers, both directly and indirectly, to comment on the required quality of rainfall estimates. The direct approach asked reviewers what they believed to be the required absolute rainfall estimation accuracy for a dekadal time step. The indirect approach asked reviewers what levels of anomaly (either in absolute or percent terms) they believed to be significant for decision making.

For rainfall estimate accuracy questions (4b), a clear majority of respondents perceived that rainfall monitoring should be accurate to within 10 mm per dekad. For 1-month forecasts, reviewers who selected an accuracy level were nearly evenly split between 10 mm per dekad and 50 mm per dekad. For 2-month forecasts, the largest group supported a 50 mm per dekad requirement. At 4 months out, the response became somewhat diffuse, although there was a trend toward relaxing the absolute requirement. For all the predicted time intervals, a noteworthy segment of respondents (from 22% to 27%) reported being unsure of whether the prediction was necessary for their analysis.

Answers to questions related to absolute anomalies (figure 4b) revealed that for rainfall, most thought that a 10 mm per dekad anomaly would be significant; most also thought that a 25 mm per dekad anomaly would be significant for a 1-month forecast. For a 2-month forecast, threshold of significance was basically split between 25 mm per dekad and 50 mm per dekad; at a 4-month forecast, the dominant responses were 50 mm per dekad and 100 mm per dekad. The data show that improving existing rainfall estimation/prediction performance is required as forecasting time increases. This response could impact future data requirements.

For relative rainfall anomalies (4c), the predominant response for minimum level of threshold of significance was 25% at every estimate prediction time; interestingly, this requirement diminished as the forecast time extended.

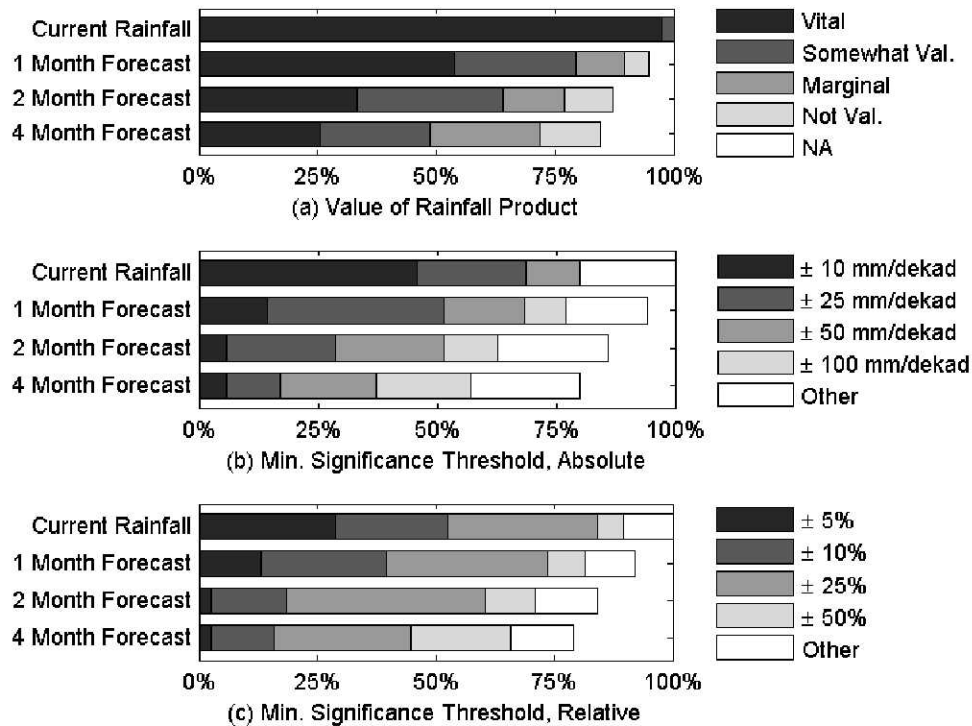


Figure 4. Breakdown of how respondents value various rainfall estimates from current (near real-time observed) through 4-month forecasts.

3.4. Results for vegetation value and accuracy

The reviewers' response regarding the value of vegetation monitoring is summarized in figure 5a. Reviewers were asked to consider both existing monitoring products as well as vegetation forecasting products under development. The responses were strongly supportive of both monitoring (>70%) and 1-month forecasts (>50%), and having estimates at those times was indicated to be "vital." At 2 months and 4 months, most reviewers considered vegetation forecasts as "somewhat valuable." Overall, the reviewers' responses revealed that vegetation was not valued as highly as rainfall, and some responders were not sure how forecast vegetation products related to their analysis or decision making.

The questionnaire asked reviewers to consider product quality in relationship to their perception of both required accuracy and thresholds of significance. For vegetation monitoring, it was challenging to word the questions because vegetation as monitored through remote sensing indices is scaled in a variety of ways. Therefore, the questionnaire asked reviewers consider a common vegetation index scale (-1 to 1) resulting directly from the NDVI formula ($NDVI = [NIR - red] / [NIR + red]$).

In general, the respondents' view of vegetation accuracy was not as well-defined as their view of rainfall accuracy. For many, the role of vegetation products for analysis and/or decision making was not necessarily clear. However, a trend in the group's response was still discernable: dominant selection of 0.02 NDVI for monitoring, 0.05 NDVI for 1-month forecasts, and 0.10 NDVI for 2- and 4-month forecasts.

As with rainfall, reviewers found that the absolute thresholds for vegetation anomalies were more lenient than their stated accuracy requirements. The most frequent selection for significance threshold was 0.02 NDVI for monitoring, but only 0.10 NDVI for 1- and 2-month forecasts, and 0.20 NDVI for 4-month forecasts (figure 5b). For relative vegetation anomalies for monitoring and 1-month forecasts, most reviewers identified 10% as a minimum threshold for significance,

while for 2- and 4-month forecasts, most respondents identified 25% as a minimum threshold for significance (figure 5c).

Overall, reviewers appreciated that vegetation required a longer temporal time step because vegetation responds more slowly to rainfall, and consequently the need for quick answers is reduced. Conversely, higher spatial resolution of vegetation was desirable and useful. Higher spatial resolution vegetation maps are also beneficial for small cropping field and mixed land uses.

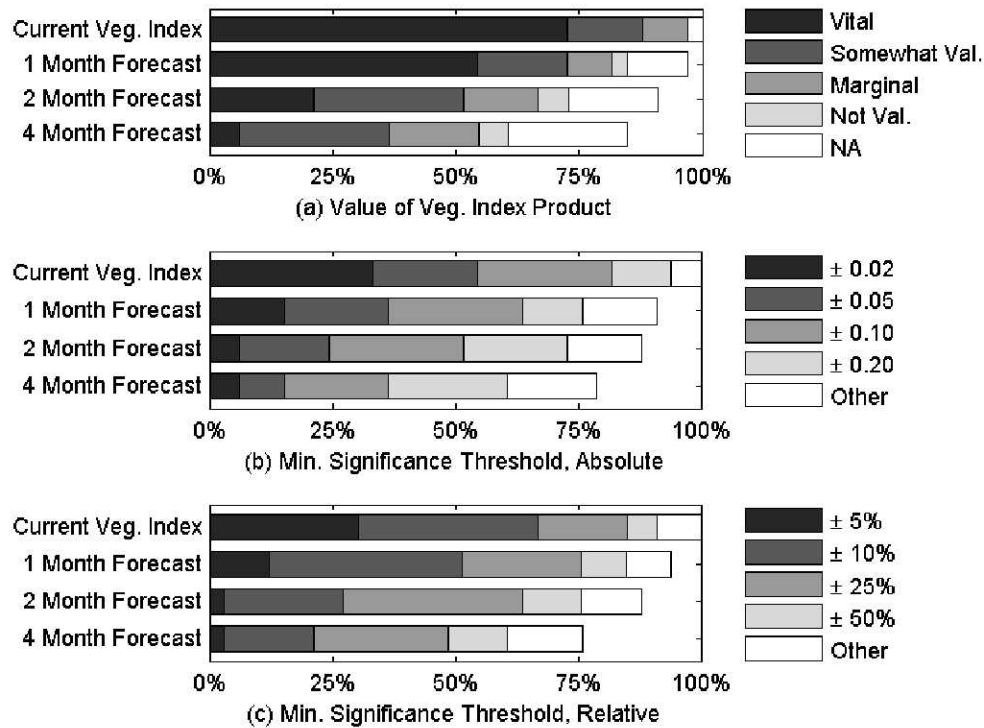


Figure 5. Breakdown of how respondents value various vegetation index estimates from current (near real-time observed) through 4-month forecasts.

3.5. Requirements summary

The reviewers unanimously agreed that rainfall is an essential component of famine early warning. Furthermore, a clear majority of respondents felt that crop yield estimates and vegetation were also vital.

The net results of the review's requirements portion are presented in Table 1. The stated requirements numbers have been inferred from the multiple choice items and accompanying comments. In some categories, multiple requirements were stated to satisfy needs arising from multiple drivers. Tables 2 and 3 provide the specific requirements for satellite rainfall and vegetation remote sensing for FEWS NET. Information from these tables can be used to derive and identify areas where improvement can be made and/or where further research is required.

Table 1. FEWS NET general requirements as inferred from review.

Property	User Requirement	Drivers
Spatial resolution	250 m to 1 km	Need to capture variations to support district level analysis
Spatial extent	2000 km to 4000 km across	Need to capture synoptic views at country and regional scales
Temporal frequency	Dekad (primary)	Established operational practice; need to capture variations from typical phenology (dekadal data satisfies those with “Monthly” needs as well)
	Daily (secondary)	Need to capture sudden onset hazards such as flooding
Latency	≤1 day	Need to quickly address sudden onset hazards
Prediction time scale	1 week and 1 month	Need to analyze and prepare for both faster and more slowly evolving hazards

Table 2. FEWS NET rainfall requirements as inferred from review.

Property		User Requirement	Drivers
Spatial resolution	Rainfall	2 km to 5 km	Somewhat relaxed because of convolving effects of topography, soils, etc.
Rainfall absolute accuracy (<i>assuming dekadal time step</i>)	Current	10 mm per dekad	Response
	1-Month forecast	30 mm per dekad	Short-range planning
	2-Month forecast	50 mm per dekad	Medium-range planning
	4-Month forecast	70 mm per dekad	Medium- to long-range planning
Rainfall anomaly relative accuracy (<i>assuming dekadal time step</i>)	Current	15%	Response
	1-Month forecast	20%	Short-range planning
	2-Month forecast	25%	Medium-range planning
	4-Month forecast	30%	Medium- to long-range planning

Table 3. FEWS NET vegetation requirements as inferred from review.

Property		User Requirement	Drivers
Spatial resolution	Vegetation	250 m to 1 km	Need to capture variations to support district level analysis
Vegetation absolute accuracy (assuming dekadal time step for index scaled from -1 to 1)	Current	0.05	Response
	1-Month forecast	0.10	Short-range planning
	2-Month forecast	0.15	Medium-range planning
	4-Month forecast	0.20	Medium- to long-range planning
Vegetation anomaly relative accuracy (assuming dekadal time step)	current	10%	Response
	1-Month forecast	15%	Short-range planning
	2-Month forecast	20%	Medium-range planning
	4-Month forecast	25%	Medium- to long-range planning

4. Discussion

By using this requirements-seeking questionnaire technique, information useful to FEWS NET professionals was obtained. Overall, it was determined that rainfall and vegetation remote sensing data provide actionable food security information for FEWS NET. Key areas where decisions were influenced by the data products were identified as follows:

- Flooding – likelihood, duration, and intensity.
- Crop – start of season, progress, spatial and temporal distribution, and projected performance.
- Drought – rainfall shortfalls, duration, spatial spread, and intensity.
- Disease – water and vector borne disease due to flooding or excess collection of water.

When temporal requirements for satellite data were being specified, respondents clearly stated that the type of hazard influences the frequency of the data requirement. For example, FEWS NET works particularly well in areas that are highly vulnerable to extreme events, such as cyclones and floods; in these situations, near real-time and daily information is required to provide enough time for reaction (Vorosmarty et al., 2000) . On the other hand, droughts are slow-onset disasters that occur more frequently; therefore, constant monitoring is important to capture these types of events (Husak et al., 2007) . Higher resolution products for both rainfall and vegetation were also of interest to FEWS NET's partners and representatives so that sub-pixel variations could be captured.

As multiple reviewers commented, spatial resolution requirements are complex. Spatial resolution needs vary according to place, time, and hazard. Perception of spatial resolution need for analysis may be skewed by knowledge of what sensor resolutions are available. Given the potential pitfalls, it is no less important to draw out some indication of spatial resolution needs for early warning systems. In general, the findings here are meant to represent the central tendency among the reviewing professionals. In this case, because of the challenges of interpretation, the spatial resolution finding may be biased toward users with more stringent needs.

The responses from the review made it apparent that both absolute and relative anomaly products are required and are of equal importance for appropriate interpretation and decision-making regarding biophysical hazards. Additionally, data products are required at varying resolutions (both spatial and temporal) and with short latency period. Therefore, although higher resolution products are needed, multiple resolutions are also useful for the same product. For example, MODIS data at 250 m, 1000 m, and 5000 m would all be useful because the lower

resolution products can be downloaded and viewed with ease; however, higher resolution imagery is also critical for sub-regional analysis. Furthermore, compared to currently available AVHRR datasets, MODIS data is known to have much higher accuracy and precision in capturing land surface conditions (Brown et al., 2006).

Some users were interested in receiving new products, in addition to those associated with rainfall and vegetation. There was an expressed interest for products that capture moisture and convectively available potential energy status, persistence, and transports.

The review also asked FEWS NET data users how decision makers use remote sensing data products. The goal of FEWS NET is to provide actionable, accurate, and defensible policy information to decision makers. A critical segment of decision makers are at the local and national governments in the region of interest. FEWS NET primarily transforms satellite remote sensing data into information that can be used by these decision makers through the local and regional representatives who have direct interaction with the data. The review targeted these representatives. Figure 6 summarizes how often respondents access selected data products that have been targeted for enhancement. The products include the RFE, the Standardized Precipitation Index (SPI), and NDVI and can be accessed through the Africa Data Dissemination Service (ADDs) portal, found at <http://earlywarning.usgs.gov> (Verdin et al., 2005).

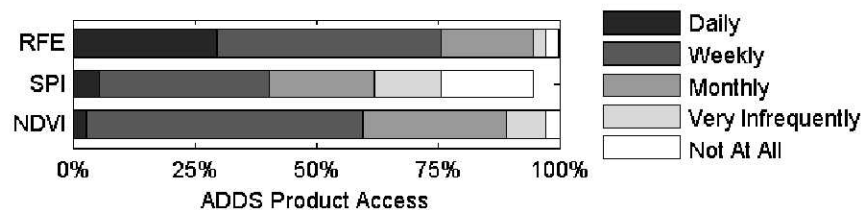


Figure 6. Reported frequency of selected data accessed through the Africa Data Dissemination Service data portal.

The results show that users predominantly use the site to download and view products to analyze prevailing climatic conditions. The reported usage is consistent with the group's assessment of temporal requirements. These products are incorporated into presentations and monthly reports and then used to inform decision makers. At the country level, the information has contributed to an increased ability to make intelligent decisions regarding food security.

Agrometeorological analyses that are carried out for decision makers are based primarily on rainfall estimates and water balance products that are offered through FEWS NET. While these products are usually obtained via e-mail, they are sometimes acquired directly from the Web site. These analyses are considered important by management and other important stakeholders. In some cases, the NOAA RFE and other products have been used as the basis for identifying problematic areas for field assessments.

For example, one reviewer explained how the amount of rainfall affected the 2006 growing season in a West African country and consequently had a significant impact upon crop production in the region. Rainfall was significantly less than normal during several dekads in July and August of that year. This caused cereal crop failures and resulted in production that only met 30% of the region's mean supply need. These crop failures rippled through the regional economy and resulted in a rise in cereal prices in affected areas. The country's famine/food security monitoring system was able to use the rainfall and price analysis provided by FEWS NET to show how the drought impacted food security in the region.

5. Conclusions

The questionnaire proved to be a useful tool that was able to derive essential FEWS NET user requirements. Table 4 links enhancements offered for FEWS NET with the perceived

requirements drawn from this FEWS NET professional review. Requirements have been labelled as follows, based upon current FEWS NET enhancement plans: MET: the requirements should be met; UNCERTAIN: unclear as to whether these requirements will be met; UNMET: the requirements will not be met.

Table 4. FEWS NET DSS requirement/NASA input match.

Element	NASA Inputs	Met/Unmet Requirements (as planned)
General	(detailed below)	MET: Daily, dekadal, and monthly time step MET: Continental coverage UNCERTAIN: Latency is expected to be 1 to 3 days; 1-day latency is a goal, but achievement will be dependent on inputs MET: Predictions at 1, 2, and 4 months (perceived requirement of 1-week forecasts not currently addressed) NOTE: Product accuracy will be addressed through verification and validation as project is implemented
Rainfall	SPI based on Tropical Rainfall Measuring Mission (TRMM) 3B42-RT	MET: New precipitation products are planned for delivery at 0.05 degrees (~5 km) vs. end-user perceived requirement of 2 to 5 km
Vegetation	Standardized Vegetation Index (SVI) based on MODIS Climate Model Grid Release 5	UNMET: New vegetation products are planned for delivery only at 5 km vs. end-user perceived requirement of at least 1 km

In summary, this questionnaire analysis has led to key findings regarding currently planned FEWS NET enhancements. The focus of NASA-funded work on rainfall and vegetation is well placed. The early warning professionals participating in the review for FEWS NET almost unanimously affirmed rainfall as a vital input. The value placed on vegetation was also quite substantial; approximately three quarters of review respondents viewed vegetation as a vital input for analysis and decision making.

Spatial coverage and temporal frequency of planned FEWS NET enhancements are generally sufficient to meet early warning needs in Africa. For the most time-critical analyses that are essential from FEWS NET, the suggested enhancement (1-day latency) may not be timely enough. Meeting the latency requirement is a project goal; however, its achievement is not assured given current inputs and resources. FEWS NET reviewers were interested in the planned 1-month predicted time scale but also wanted 1-week predicted time scale for biophysical parameters.

The survey found that many users would like higher resolution products than are currently planned. Although the dominant label “District” was viewed as the most important spatial scale of analysis, when quantifying the spatial resolution for that scale of analysis FEWS NET reviewer comments reflected an interest in finer resolution. This opinion would limit use of current systems (such as AVHRR, MODIS, and TRMM). Therefore, if these FEWS NET review comments (that suggest resolution and scale labels need to be connected) are valid, some planned products may fall short of FEWS NET requirements.

The limitations of the review presented here include the fact that the number of responses was small and was limited only to FEWS NET community, and the lack of longitudinal information. It would have been interesting to apply this same survey to a broader community, one which

included for example those partners with whom FEWS NET works in country, individuals in the government and in influential non-profit organizations. Although this would gather interesting information that could be compared to that which is presented here, it would extend the results beyond what are the actual requirements of FEWS NET and its partners, which was the goal of the project. Eliciting the requirements for the specific work of FEWS NET was a key goal of the review, one which could not be served by extending the questionnaire beyond immediate employees of the network.

The survey responses have already influenced FEWS NET operations, through its willingness to invest in higher resolution and better quality rainfall and vegetation data, and through a transformation of its web site portal to provide analysis at the same time that data is presented. Higher spatial resolution products, made possible by continued improvements in satellite technology and computing power, will be appreciated by FEWS NET analysts. By involving the producers of biophysical data and information in the monitoring and response to food security, FEWS NET has motivated the improvement in the kind of quantitative information required to identify food security problems as early as possible. Continued personnel support, or base funding, is a key way that further improvements in the data used by FEWS NET and its analysts can be supported.

Through this review, it is clear that there is a diversity of opinions about the optimal spatial and temporal resolution for the current products used in food security analysis. Future work will clearly benefit from an expansion of the number of people included in research focused on understanding which products are most useful and their format. Understanding the needs of people outside of the FEWS NET community would enable an improved use of technology in the effort to gain consensus on food security crises and build capability locally, two primary FEWS NET goals.

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